Fermi National Accelerator Laboratory

FERMILAB-Pub-80/31-EXP
7420.180

(Submitted to Phys. Lett.)

MEASUREMENT OF SU(3) SYMMETRY VIOLATION IN THE QUARK JET

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March 1980

ABSTRACT

We have used the ratio between the production rates of K^0's and π^-'s in antineutrino-nucleon interactions in the Fermilab 15-Ft. bubble chamber to measure the size of the SU(3) symmetry violation in the production of quark-antiquark pairs to be 0.27±0.04. This value is significantly larger than the value obtained from a recent ep experiment. There is no apparent dependence of the K^0/π^- ratio with W^2, Q^2, x_B or p_T^2.

Hadron production in the current fragmentation region of deep-inelastic lepton-nucleon scattering is successfully described by the cascade model of quark fragmentation[1]. One of the parameters of this model is the degree of SU(3) symmetry violation which appears as a relative suppression of the strange quarks in the formation of new quark-antiquark pairs in the quark jet cascade. The fastest particle in each jet is assumed to be the most probable carrier of the original fragmenting quark. In antineutrino-nucleon charged-current interactions the fragmenting quark is predominantly a d-quark. The relative amount of fast K^0-mesons ($d\bar{s}$) to the amount of fast π^-'s ($d\bar{u}$) then provides a direct measure of the probability of producing a $s\bar{s}$ pair (γ_s) versus an $u\bar{u}$ pair (γ_u) in the quark jet cascade.

In the cascade model the non-strange quark-antiquark pairs were taken to be twice as probable as the strange pairs, i.e. γ_s/γ_u=0.5. This value strongly disagrees with a recent result from an electroproduction experiment[2] which claimed considerably stronger SU(3) violation.

In this letter we consider neutral kaons K^n(K^0 or $\bar{K}^0$) and negative hadrons h^-(π^- or K^-) produced in the current fragmentation region of deep-inelastic antineutrino-nucleon charged current interactions. The experimental analysis is based on ~ 155,000 pictures obtained using the Fermilab 15-Ft. bubble chamber filled with a heavy neon-hydrogen mixture. Further details of the selection of the charged current events and a complete description of the K^n sample are given elsewhere[3].

In the present analysis we have used only those charged primary hadrons for which the relative error in momentum was less than 30%. It is not possible to make an unambiguous mass assignment for the charged hadrons with momentum greater than ~ 1 GeV/c. For the negative tracks the majority are pions (>90%) and in the calculation of the kinematic variables the pion mass was assigned to all negative particles. All the accepted tracks were then weighted to compensate for losses due to the close-in secondary interactions[4].

The selection for current fragments was made in the hadron center-of-mass system (c.m.s.) by requiring $x_F=2p_L^*/W$ to be positive (p_L^* and W are the hadron momentum along the current direction and the total hadronic energy in the hadronic c.m.s., respectively). In order to reduce the overlap between the target and current fragmentation regions[5] we select $W^2 > 4$ GeV^2 and $Q^2 > 1$ GeV^2/c^2 (Q^2 is the square of the four-momentum transfer between the incoming antineutrino and outgoing muon). We suppress the effects of hadron production off sea quarks in the target nucleon by the selection $x_B=Q^2/2m\nu > 0.1$ where $\nu=E_{\bar\nu}-E_\mu$ is the total hadronic energy in the laboratory system and m is the nucleon mass[6]. The sample passing these criteria consists of ~4330 charged current events with $E_{\bar\nu} > 10$ GeV and includes 540 K^n mesons (for K^n's corrections for all experimental detection efficiencies and K_L^o production were made).

The number of K^n mesons relative to the number of h^-'s in a fixed fractional hadron energy interval $\Gamma_z < z < 1$, where $z=E_n/\nu$, increases as a function of the lower limit Γ_z up to $\Gamma_z \sim 0.3$ and shows no clear dependence on Γ_z for the region $\Gamma_z > 0.3$ (Fig. 1).

We assume that the constancy of the ratio above $z=0.3$ allows a separation of the quark fragments. We then estimate the K^0/π^- ratio at $z=1$ using the experimental value at $\Gamma_z=0.3$ and neglect possible effects from resonance production and non-primary mesons. This gives for the SU(3) symmetry violation

$$(\gamma_s/\gamma_u)_{exp} = 0.25\pm0.03$$

Contamination from fast $\bar{K}^0$'s and K^-'s arises mainly from fragmentation of s and $\bar{u}$ quarks, respectively, and at $z=1$ results in a ~8% correction to the above value[7]. Here we neglect the non-primary mesons because the average jet multiplicity in the region $z>0.3$ is low (~ 1).

In Fig. 2a-2d the K^n/h^- ratio in the current fragmentation region ($z>0.3$), which reflects SU(3) breaking, is shown as a function of the variables W^2, Q^2, x_B and p_T^2 (here p_T^2 is the squared transverse momentum of a hadron with respect to the current direction). No obvious dependence is seen in these variables in the energy range accessible in this experiment. Using quark and antiquark densities obtained in this experiment[8] and using our value for γ_s/γ_u we calculate[7] the K^n/h^- ratio as a function of x_B (solid curve in Fig. 2c). The agreement between the experimental points and our calculation is good in the region $x_B>0.1$. In the region $x_B<0.1$ (see Fig. 2c) some evidence for charmed particle production is seen[8].

Up to the present we have ignored the effects of resonance production and non-primary mesons in our analysis. To account for these effects in our determination of the ratio γ_s/γ_u we have used the analytical approximation for the quark fragmentation functions given by Field and Feynman[1]. In Fig. 1 we show the predictions obtained using these fragmentation functions with different values of the parameter γ_s/γ_u (from 0.2 to 0.5). In order to make the model calculation agree with our measured K^0/h^- ratio at Γ_z=0.3 we must use the following value for γ_s/γ_u in the above model:

$$(\gamma_s/\gamma_u)_{FF2} = 0.27 \pm 0.04$$

This results in a ~ 10% larger SU(3) symmetry breaking than measured without the model corrections. Our result is approximately one half the size of SU(3) symmetry violation used in previous applications of the cascade model[1]. These applications were insensitive to the exact value of the γ_s/γ_u term. The γ_s/γ_u ratio measured here agrees well with the value ~ 0.27 extracted from the quark jet net charge extrapolated to infinite W in the same experiment[5]. On the other hand, our result does not agree with the value of 0.13±0.03 obtained in the ep experiment[2].

One of us (R.O.) would like to thank R.D. Field and R.P. Feynman for useful discussions.

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The relative antiquark contamination is estimated to be ~6 % in the region $x_B > 0.1$.

[7] The calculations were carried out at z=1 for the non-resonant primary mesons (mesons containing the original quark), only, and takes into account the dominant transitions $u \to d$ ($\sim \cos^2\theta_c u(x)$), $u \to s$ ($\sim \sin^2\theta_c u(x)$) and $\bar{d}(\bar{s}) \to \bar{u}$. We used the sea-quark density distributions as measured in our experiment (Ref.6).

[8] Details on charm effects in our $\bar{K}^n$ and Λ sample are discussed in a forthcoming paper.

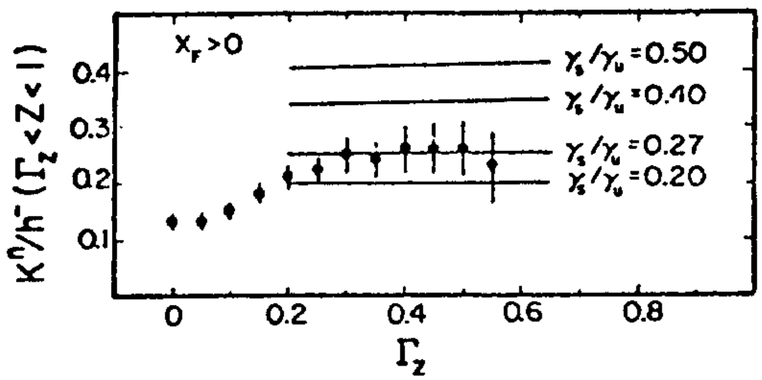

Fig. 1: The K^n/h^- ratio in the region $\Gamma_z < z < 1$ as a function of the lower limit, Γ_z. The cascade model calculation for different theoretical γ_s/γ_u values are shown by solid curves.

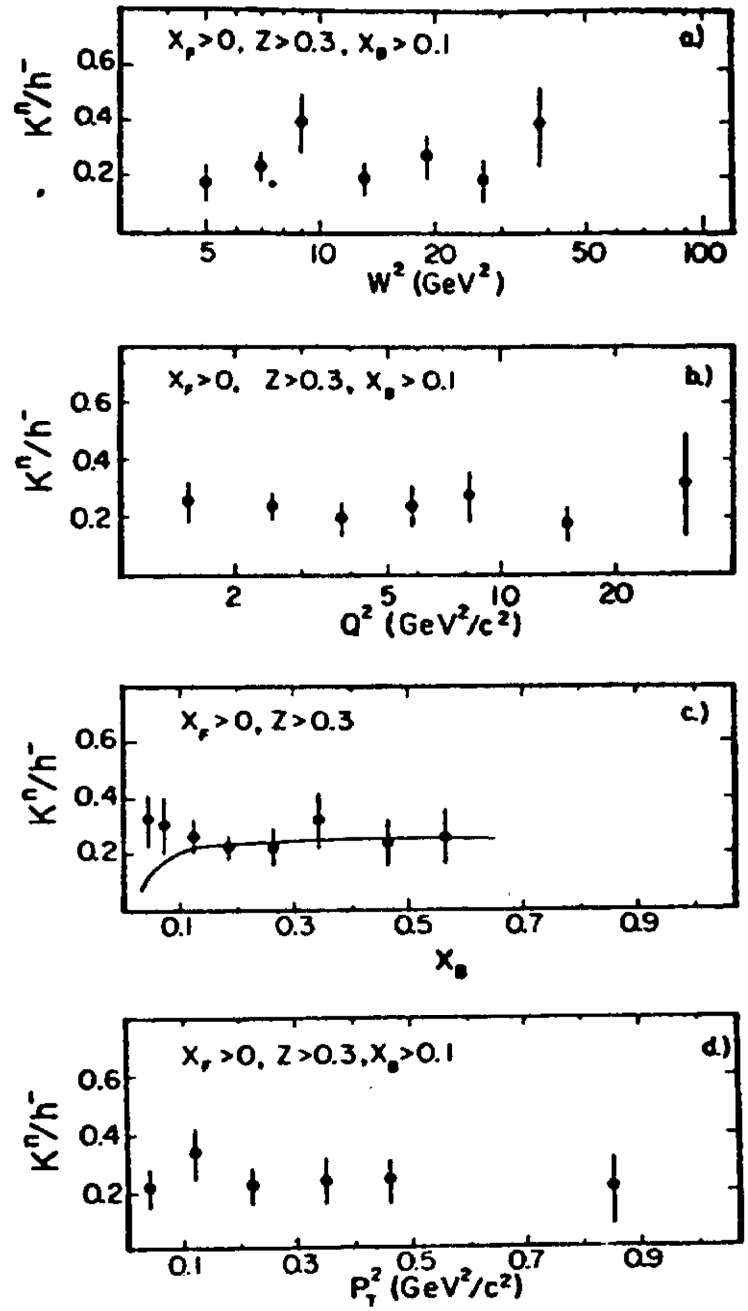

Fig. 2: The K^n/h^- ratio ($x_F > 0$, $z > 0.3$) as a function of W^2 with $x_B > 0.1$ (a), Q^2 with $x_B > 0.1$ (b), x_B (c) and p_T^2 with $x_B > 0.1$ (d). The solid curve is described in the text.